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Research under this grant, an extension of Grant #N00014-98-1-0813 that supported the completion of the Ph.D. thesis of Christopher L. Wolfe, focused primarily on computations of unstable nonlinear periodic solutions, time-dependent normal modes (Floquet vectors), and singular vectors in a two-layer quasi-geostrophic channel model. The model was studied in a strongly nonlinear regime, in which small disturbances to an unstable, steady, zonal, baroclinic shear flow grow to finite amplitude and continue to vacillate irregularly for arbitrarily long times. The computation of time-dependent, normal-mode disturbances to unstable, nonlinear, time-periodic basic flows in a high-dimensional geophysical fluid model opens a new perspective on the analysis of disturbance growth in time-dependent flows, and on the closely related problem of error growth in predictive models of time-dependent flows.

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ONR GRANT #N00014-06-1-1369

PI: Roger M. Samelson
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The results of this one-year extension confirm and extend the results reported for the previous Grant #N00014-98-1-0813. In the strongly nonlinear regime, unstable periodic solutions were identified and computed using an efficient Newton-Picard method. The complete Floquet and singular vector spectra were computed for strongly nonlinear cycles and the dynamical structure of the resulting modes were analyzed. The Floquet vectors fall into two classes with direct physical interpretations: wave dynamical (WD) modes and damped-advective (DA) modes. Singular vectors were computed and analyzed in terms of the two classes of normal-mode solutions, and showed a similar dynamical splitting. A new, efficient method was developed for the recovery of Lyapunov vectors from singular vectors, which promises the possibility of computing Lyapunov vectors directly for the first time for very large systems such as numerical weather prediction models.

LIST OF PUBLICATIONS

Wolfe, C. L., and Samelson, R. M., 2006. Normal mode analysis of a baroclinic wave-mean oscillation. Journal of the Atmospheric Sciences, 63, 2795-2812.
Wolfe, C. L., and R. M. Samelson, 2007. An efficient method for recovering Lyapunov vectors from singular vectors. Tellus, accepted.
Wolfe, C. L., and R. M. Samelson. Singular vectors and time-dependent normal modes of a baroclinic wave-mean oscillation. Journal of the Atmospheric Sciences, submitted.